Thermal Desorption Spectroscopy Studies of Hydrogen Retention on FLIRE

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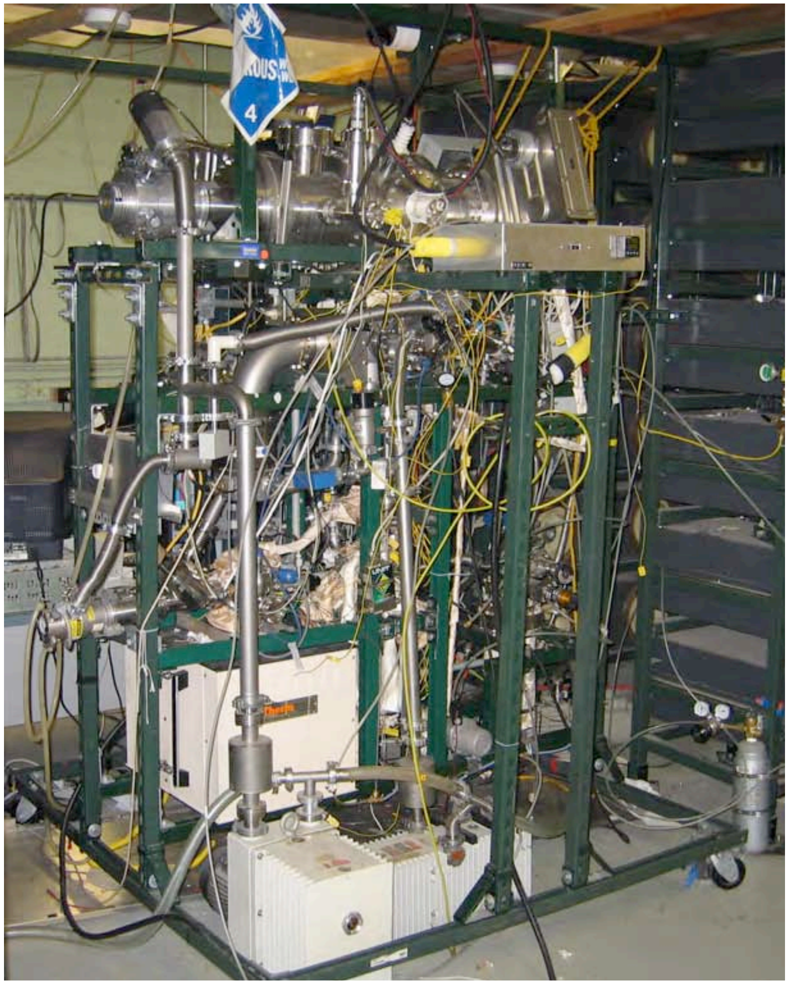
Overview

- Brief overview of design of the Flowing Liquid Retention Experiment (FLIRE)
- Review Helium Retention and Diffusivity
- Thermal Desorption Spectroscopy (TDS) measurements of deuterium absorption in flowing lithium



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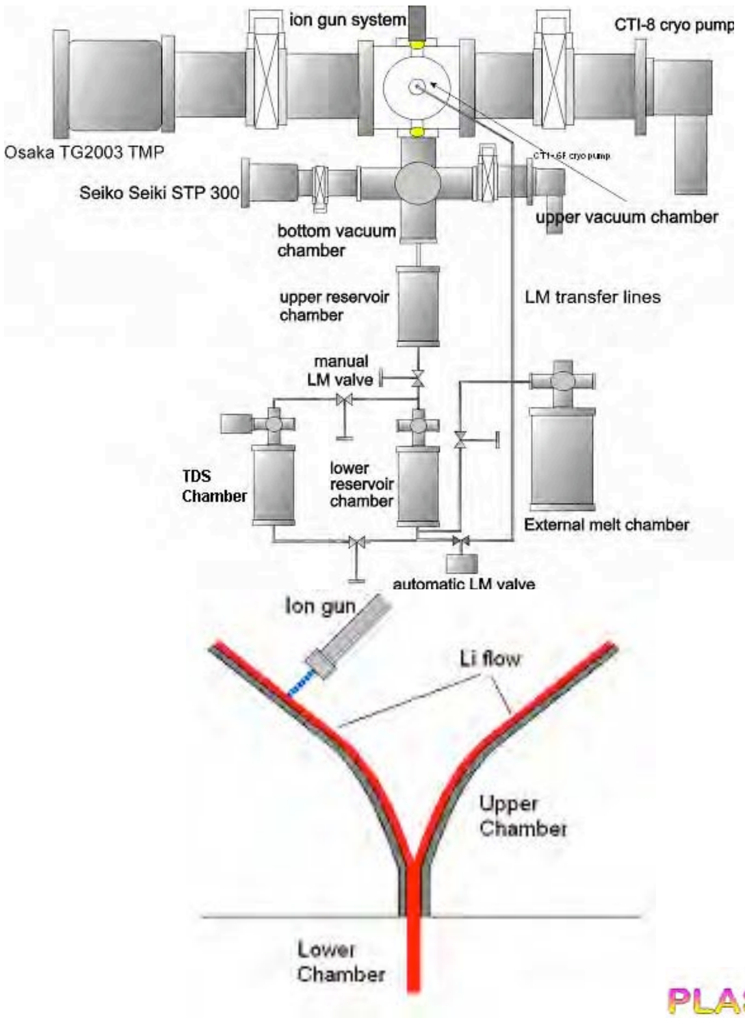
FLIRE Design

- Two ramps with Li flow converge and form a vacuum seal between the upper and middle chamber
- Middle chamber monitored for prompt release
- TDS chamber used to release long-term trapped species, such as deuterium
- Middle chamber and TDS chamber share MS-RGA (gate valves isolate chambers)
- Lower reservoir pressurized to move lithium upper chamber
- Thermal Desorptsion Spectrometry (TDS) chamber can reach 1200C



Objectives of FLIRE

- Prior work
  - Demonstrated helium pumping with quantitative measurement of Helium retention in flowing liquid lithium, estimate diffusion coefficient
- Present work
  - Develop plasma source for higher implanted hydrogen flux in flowing lithium
  - H desorption kinetics measurements with lithium after plasma/beam exposure using thermal desorption spectroscopy
- Future Work
  - Revisit He work with plasma source
  - Retention and diffusivity measurements with other candidate liquid PFCs, such as tin or gallium
  - Design upgrade to FLIRE facility to accept pulse plasma gun and magnet assemblies

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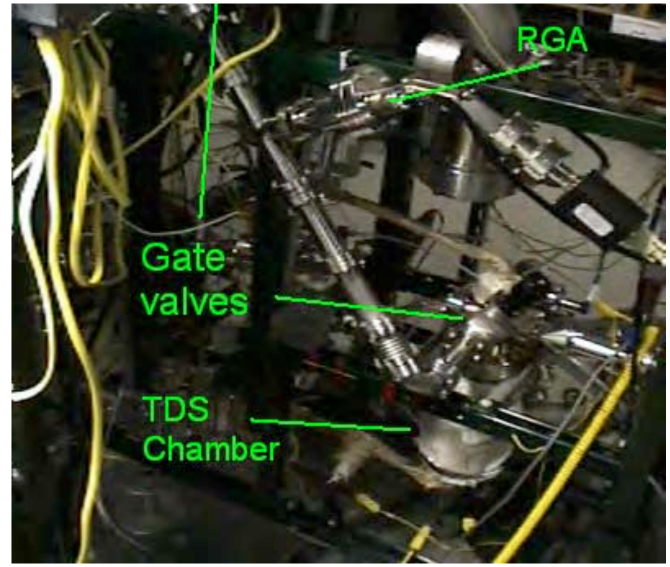
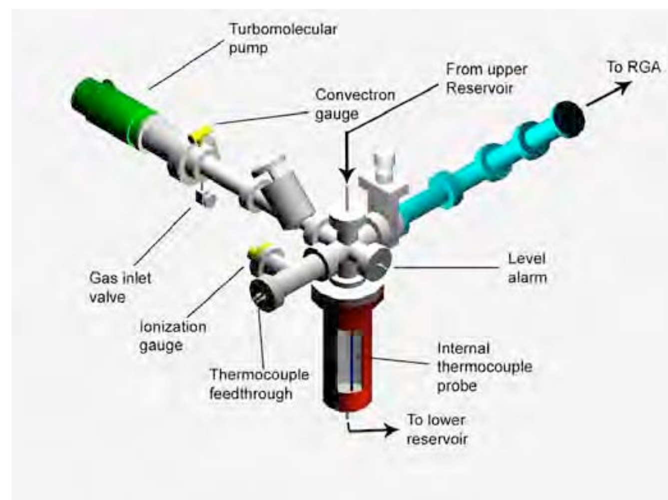
Thermal Desorption Spectroscopy (TDS)

- Lithium sample is heated linearly from 220 °C to 600°C at 2°C/minute
- Magnetic Sector RGA (good low-mass sensitivity) looks at gas evolution in TDS tank
- Temperature at which deuterium peak is observed is correlated to deuterium concentration via phase diagram





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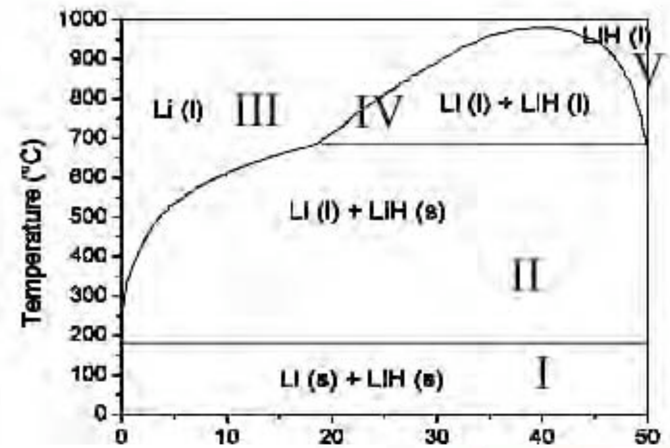
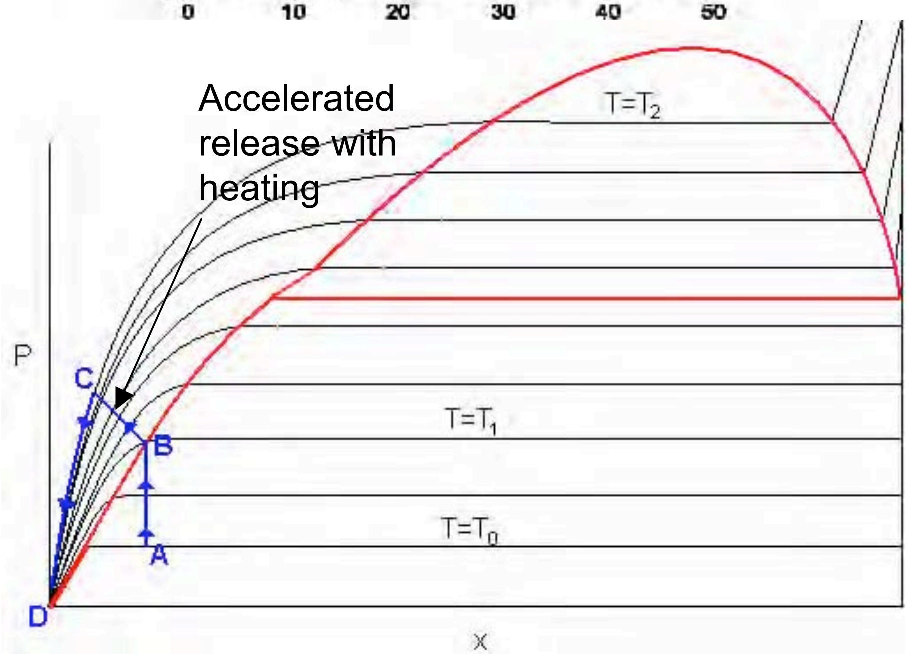
Lithium Hydrogen System

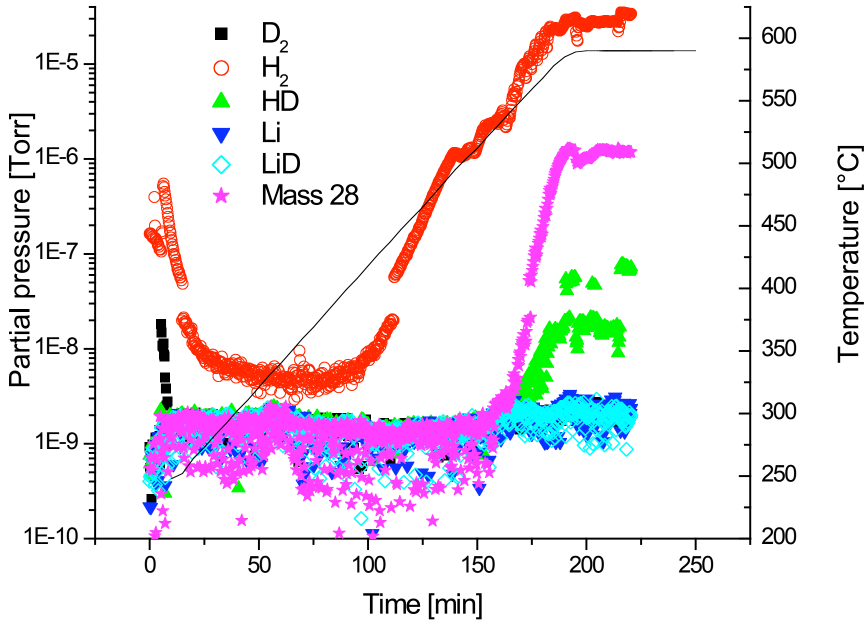
- Phase diagram shows transistion from Li(l)+LiH(s) to only Li(l) for concentration <19%
- H is everywhere; deuterium (D) is used as traceable substitute
- D concentration can be determined by temperature at which peak desorption occurs





Flowing Lithium Neutral (molecular) Deuterium Exposure

- 7×10^{-5} Torr and 1 Torr deuterium pressure at 230 C
- Initial spike with temperature increase from 230 C - 250 C upon entering TDS chamber
- Immediate D_2 release from Lithium indicates low lithium-deuteride concentration (~0.2%)
- Similar results could be due to limited exposure time
- Try longer duration tests on lithium pool with static gas fill



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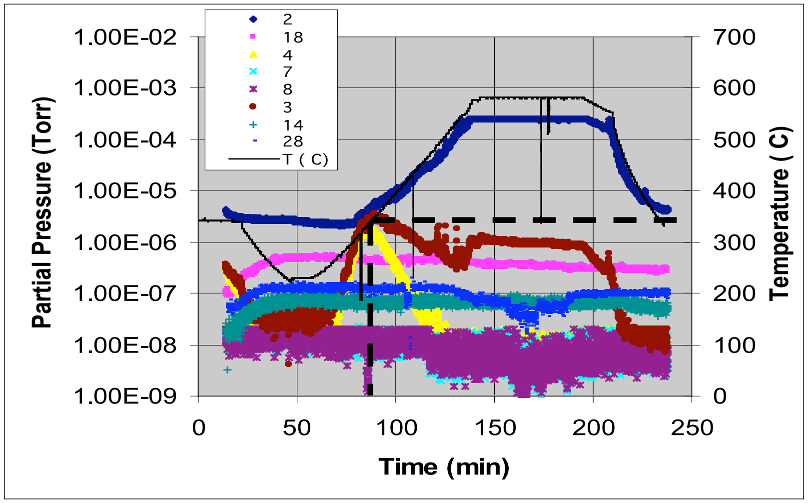
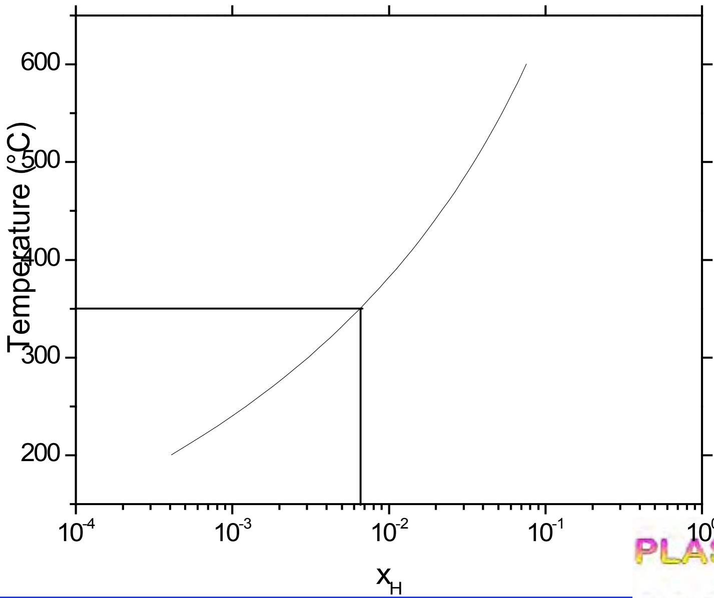
Static Lithium Neutral (Molecular) Deuterium Exposure at 1 mTorr

- Static pool of clean fresh lithium at 350°C
  - Exposed to ~1mTorr of deuterium gas for 10 minutes
  - Cooled to 220°C and then ramped up to 600°C
- Desorption peak appears as HD and D_2 at 350°C, corresponds to the temperature of D_2 exposure and ~0.7% LiD
- Sample soaked at 600°C to clean up impurities





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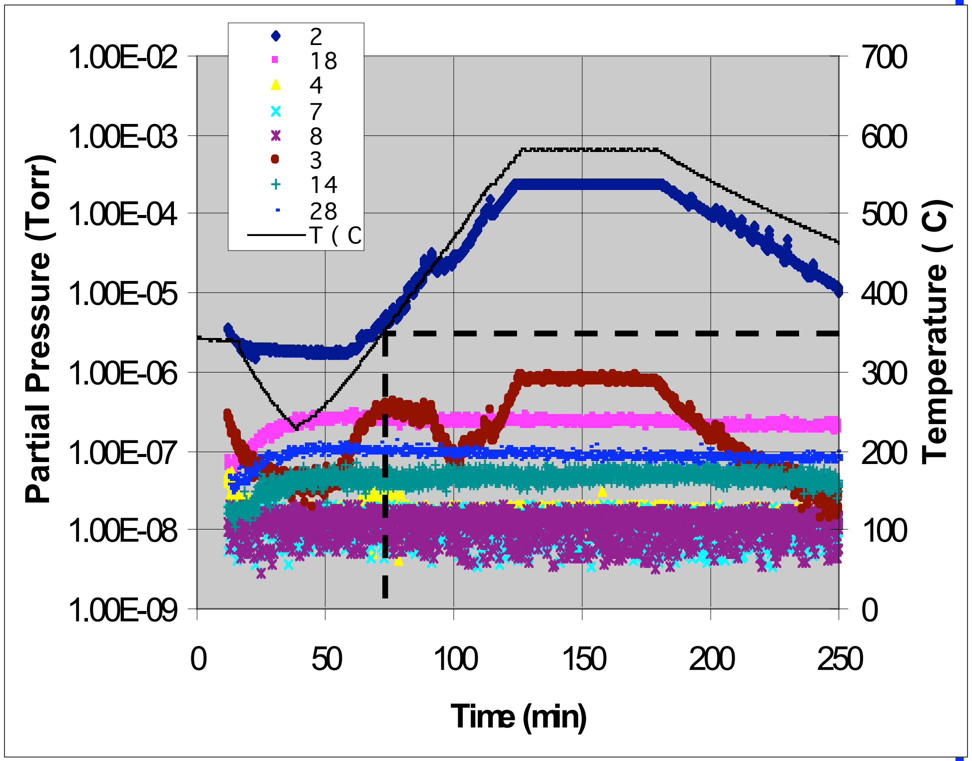
Static Lithium Neutral (Molecular) Exposure at 0.07 Torr

- Same lithium (cleaned by 600°C bakeout) at 350°C
  - Exposed to ~0.07mTorr of deuterium gas for 10 minutes
  - Cooled to 220°C and then ramped up to 600°C
- Again, desorption peaks appear at 350°C



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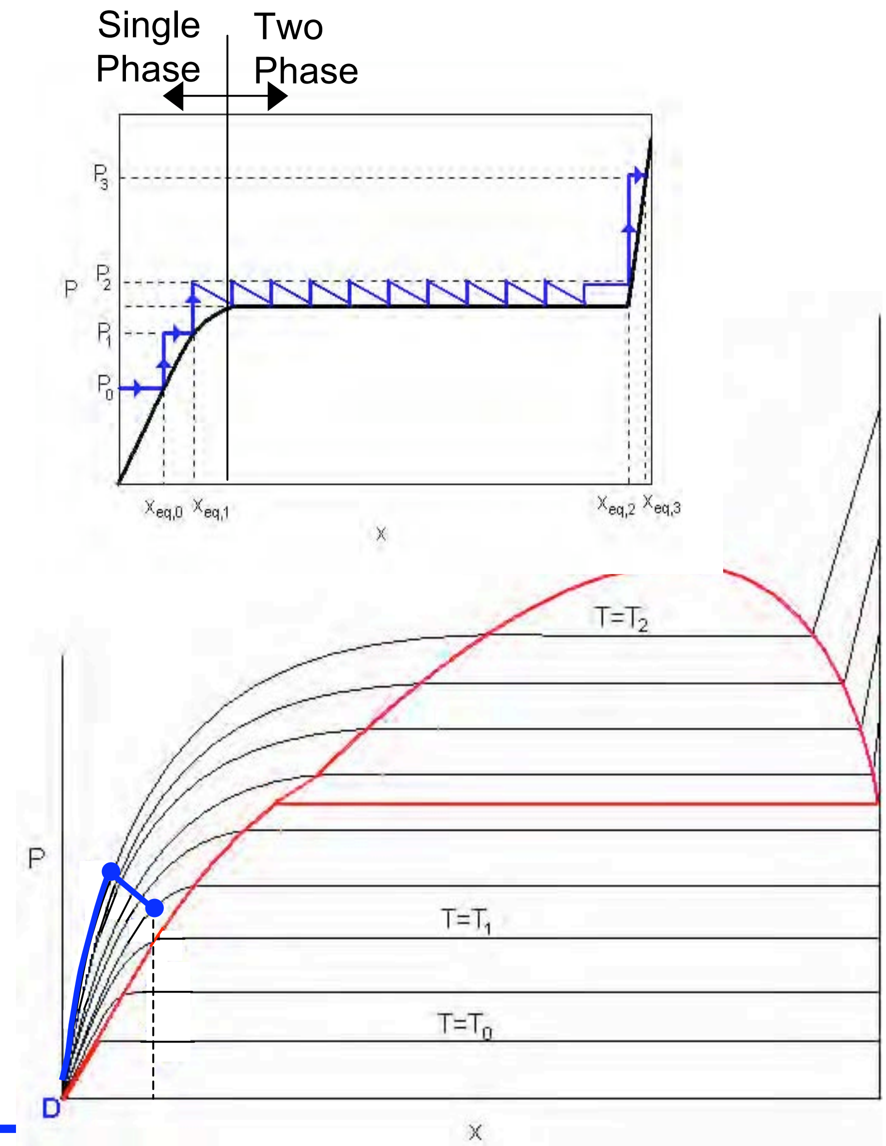
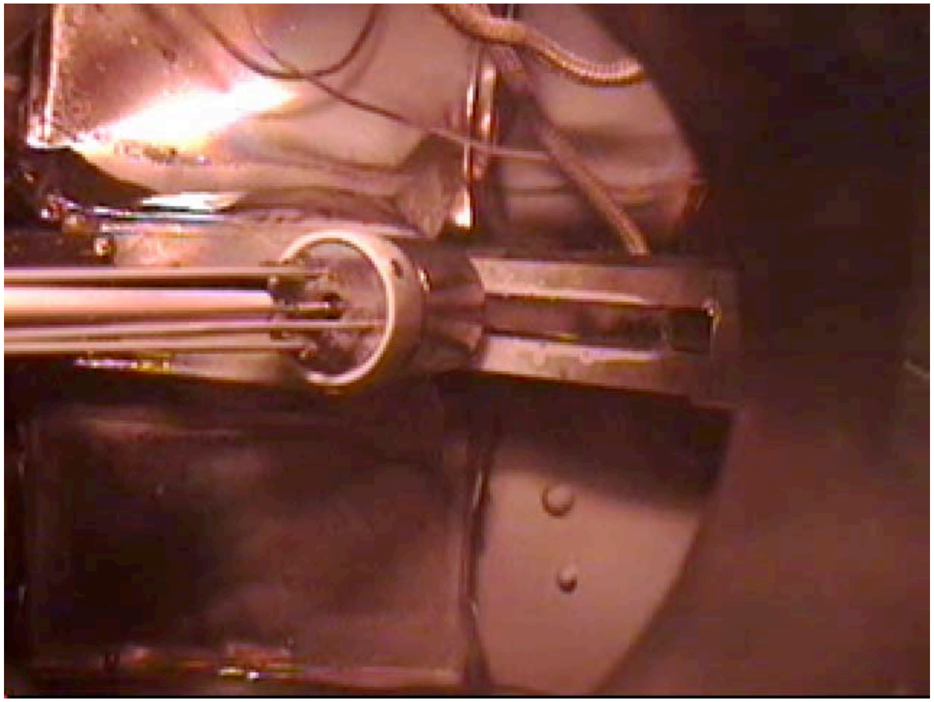
Equilibrium

- Lines in phase diagram is not at constant pressure
- Lithium deuteride concentration is insensitive to exposure pressure in the single phase region
- Pressure required to reach two-phase region was not reached for long-duration exposures at 350°C
- If hydrogen (D/T) is IMPLANTED – a very high effective pressure – higher concentrations can reached



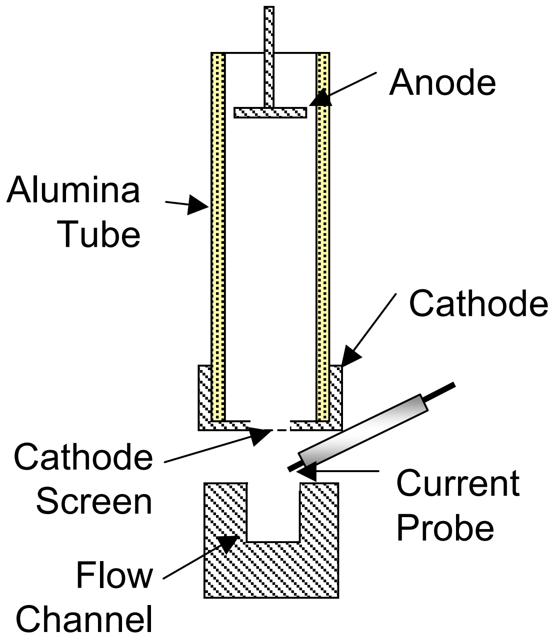
Deuterium Plasma Exposure

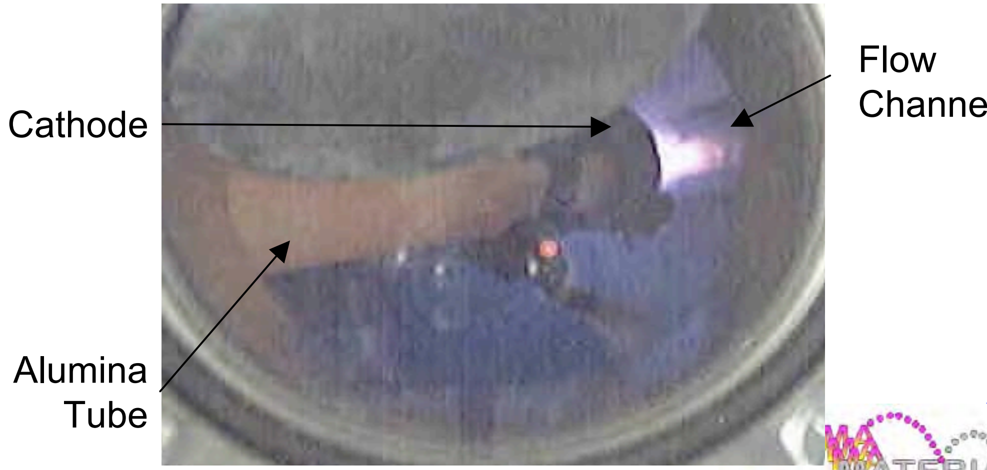
- With divertor-plasma exposure, two-phase region may be reached, despite high temperatures and low pressures
- FLIRE provides a means of measuring deuterium absorption in flowing lithium – necessary data for designing a flowing lithium divertor
- Ion gun used for helium retention measurements is too weak for hydrogen measurements
- Need more intense plasma source to separate neutral gas contribution from implanted contribution



Simple Plasma Source

- Two-electrode DC plasma source
- Cathode is near ramp
- Cathode is grounded, prevents discharge throughout chamber
- Screened hole in cathode allows ion extraction
- In-situ probe monitors ion current to lithium continuously
- Operate source at low-enough pressure to avoid two-phase region – keeps absorption due to background gas low
- Plasma fills entire length of ramp from inlet to outlet





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Plasma Source in Operation

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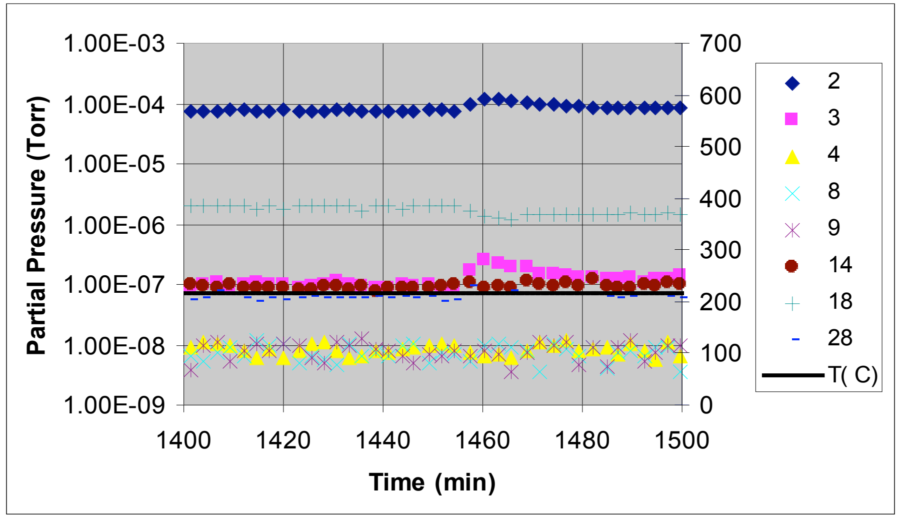
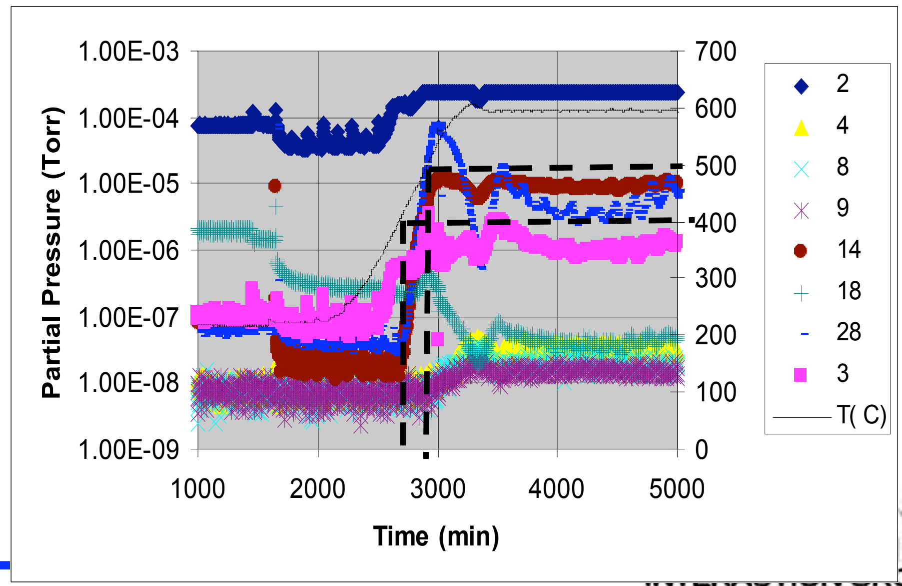
Prompt Release

- 180 mTorr of D_2 gas
- 800 V, 32 mA discharge (ion current needs to be calibrated)
- Flow speed ~20 cm/s
- As with helium measurements, a vacuum seal is maintained and prompt release is observed during the flow only
- TDS trace indicates a peak at 400-500 °C
- Corresponding LiD concentration is 2-4%
- Much higher than previous flow measurements with only deuterium gas





Next Steps

- Additional neutral gas absorption experiments at varying pressures, flow rates and temperatures to fully characterize background gas absorption
- Additional deuterium absorption measurements with plasma source to verify absorption greater than neutral gas case
- Calibration of ion current from gun
- Estimate of fast atomic D flux on surface

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Conclusions

- Neutral gas experiments reproduce points on Li/LiH phase diagram, confirming FLIRE's ability to quantify hydrogen retention in flowing lithium
- Neutral gas experiments also suggest that absorption of background deuterium (required to operate plasma source) will not lead to two-phase region – background gas absorption should be limited to low levels allowing effect of plasma to be isolated from background gas
- Plasma exposure seems to lead to higher hydrogen retention, as expected
- More data with FLIRE's plasma source is needed to verify and quantify higher retention

Acknowledgements

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